UNIVERSAL WIRELESS PROGRAMMER

EDL Project

S-01 Tue-16

PROBLEM

What is the problem
we are trying to solve?

Use Case #1

A highway speed limit checker camera's threshold can be remotely adjusted from the control center, allowing quick updates when lanes expand or limits change. AI can further optimize these adjustments dynamically.

Devices with no Wi-Fi Module

Many devices have no Wi-Fi modules on them which makes them unable to connect wirelessly.

No remote access to sensors

Have to connect controller to PC using cable to monitor the system which may affect the freedom of the system, hence the range of the data observed.

Use Case #2

As space manufacturing advances, our wireless programmers can be highly useful. With a superior antenna, they eliminate the hardware overhead and range issues of Wi-Fi and Bluetooth in space stations.

Devices with no Bluetooth Module

Bluetooth and Wi-Fi modules are not available on all devices and they have too much hardware overhead.

PROPOSED SOLUTION

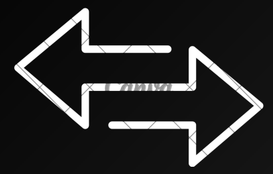
What is the value proposition of our solution?

In a nutshell...

A pair of ICs with RF communication using FSK modulation, designed for seamless wireless data transmission. The system includes a smart programmer that adapts to the end processor, ensuring compatibility across different platforms. This allows for universal integration with various microcontrollers, FPGAs, and development boards

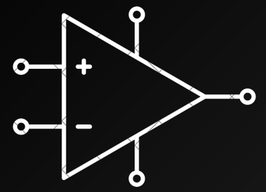
Wireless Communication

We have our own communication module which removes the need for Wi-Fi or Bluetooth.



Bi-directional Communication Channel

The bi-directional channel can get sensor readings wirelessly without having to waste RX TX ports.



Custom RF Circuits

Tuned RF circuits that can be programmed by the user for specifications like range , data-rate, bandwidth and power-saving mode.

Universal Programmer

Universality ensures that our programmer can adjust to any microcontroller.

FSK Modulation Over Wi-Fi/Bluetooth Alternatives

- Wi-Fi and Bluetooth were ruled out due to hardware overhead, internet dependency, and unavailability in some embedded devices.
- FSK (Frequency Shift Keying) modulation was chosen for its reliability, noise resistance, and low power consumption.
- The RF system operates without internet, making it suitable for applications in IoT, space, and surveillance.

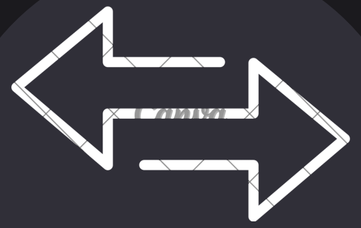
Wireless Communication

Adaptive Frequency Selection for Power and Range Optimization

Low-bandwidth mode is used for short-range operations, while high-bandwidth mode enables long-range programming.

Half-Duplex Communication via Transmission Gate Design

- Our initial design required two pairs of antennas for simultaneous Rx/Tx, but this was inefficient.
- We implemented a transmission gate digital logic design, which switches between Tx and Rx based on a clock signal.
- This allows one RF channel to handle both programming and sensor monitoring, reducing hardware complexity.



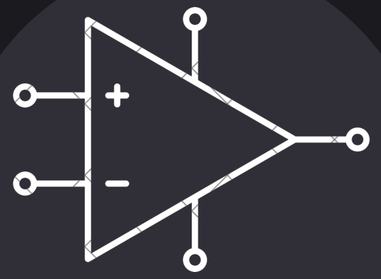
Bi-directional Communication Channel

Link-Layer Error Detection & Security Mechanism

- A link-layer protocol is implemented to verify successful data transmission and handle retransmissions.
- The system supports packet acknowledgment (ACK/NACK) responses, ensuring data integrity
- A security handshake prevents unauthorized programming by using randomized encrypted authentication keys.

High-Efficiency RF Front-End with Amplification & Matching Network

- We designed a custom RF circuit with an optimized matching network to ensure maximum power transfer to the antenna.
- The circuit includes low-noise amplifiers (LNA) for reception and power amplifiers (PA) for transmission.
- Careful impedance matching between the amplifier and antenna module maximizes signal strength.



Custom RF Circuits

Configurable RF Module for Universal Use Cases

- Unlike fixed-frequency RF modules, our system can dynamically adjust operating frequency and power output.
- The system can be reconfigured for long-range IoT applications or high-speed local programming.

Configurable Interface for Multi-Platform Support

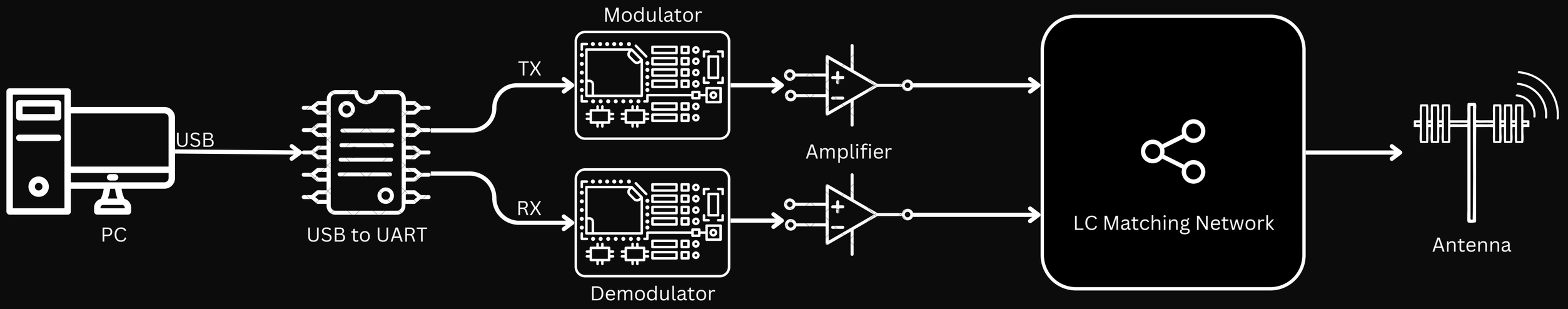
- Instead of designing separate modules for different microcontrollers, we developed a universal hardware interface.
- The Rx module is an intelligent interface that adapts to different processors.
- This eliminates the need for multiple programming hardware, making it adaptable across devices.

Universal Programmer

Efficient Programming with Byte-Level Updates & Serial Monitoring

- Our assembler detects changes in hexfile and only transmits modified bytes, reducing update time.
- The Rx side controller receives UART-based programming commands and converts them into USB protocol for the target device.
- Wireless serial monitoring and plotting are integrated, allowing real-time sensor data retrieval.

PRINCIPLE OF OPERATION

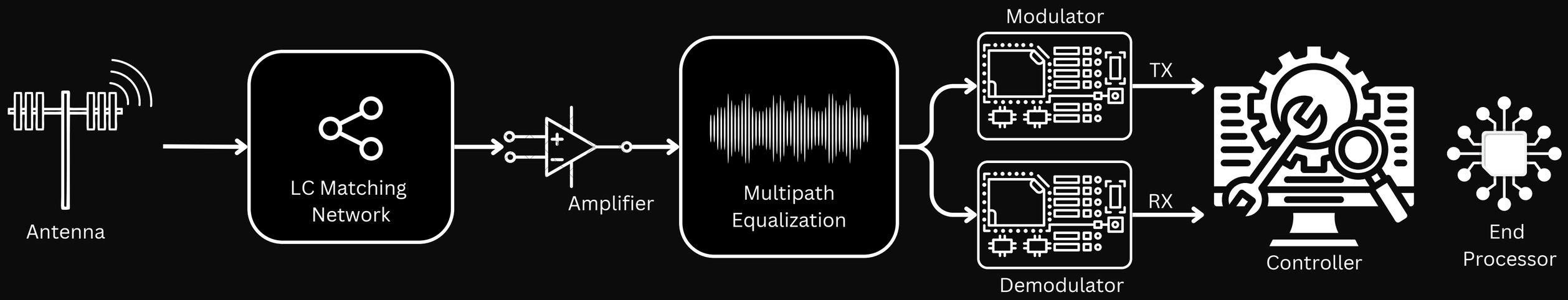


TX

Optional Components:

- Level Shifter

PRINCIPLE OF OPERATION



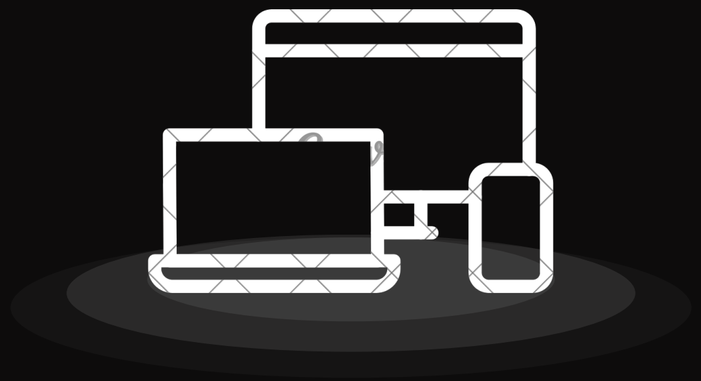
RX

Optional Components:

- Level Shifter

TARGET SPECIFICATIONS

100 kbps Datarate



Compatible with atleast 2 Processors

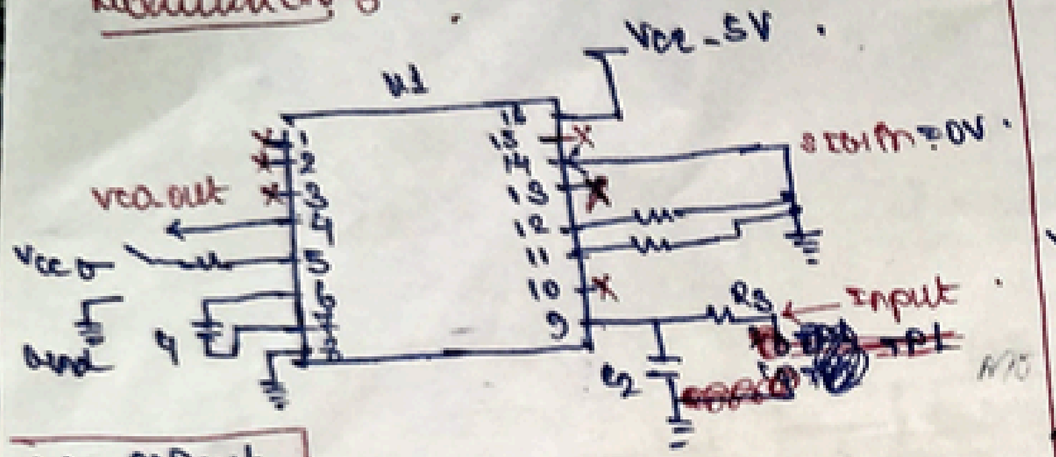
Minimum 1m^2 Range

COMPONENTS	JUSTIFICATION
Tx Interface	Bidirectional USB to Serial converter. Available in WEL .
Level shifter	High slew rate and bandwidth
Modulator/Demodulator (PLL)	supports UART datarate, frequency separation of upto 20MHz.
Connector for Antenna	It is standard
Test board	Selected for demonstration as it is one of the most common development boards that does not support OTA programming
Test Sensor (e.g. temperature, ultrasonic, etc.,)	To demonstrate readings being sent back
AND GATE (for but not gate), NOT GATE, TRANSMISSION GATE	High speed THT logic IC to control switch between Forward and backward communication
High speed Comparator	High speed comparator. Available in WEL
Buffer	Buffer to store incoming and outgoing packets at various locations
Crystal Oscillator for timer module	To set a time for receiving data

KEY RISKS	MITIGATION STRATEGIES
Rx interference from other devices	User can select from a set of frequency bands
Transmission Range and SNR	Range and SNR improved by shifting to high power mode
Corrupted Data Received or failed transmission	ACK/NACK bits are sent to ensure that the transfer was successful

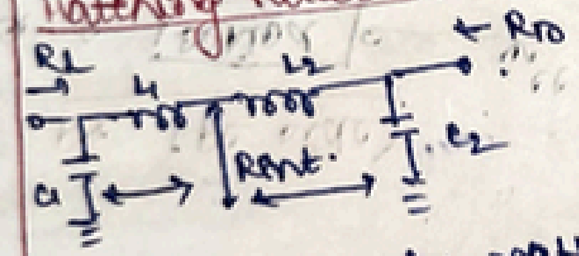
Circuit Diagrams

Modulator &



1 → PCP out
2 → PC1 out
3 → COMPin
4 → VCO out
5 → INH
6 → C1A
7 → C1B
8 → GND
9 → VCOin
10 → DEMout
11 → R1
12 → R2
13 → PC2out
14 → SIGin
15 → PC1out
16 → Vcc

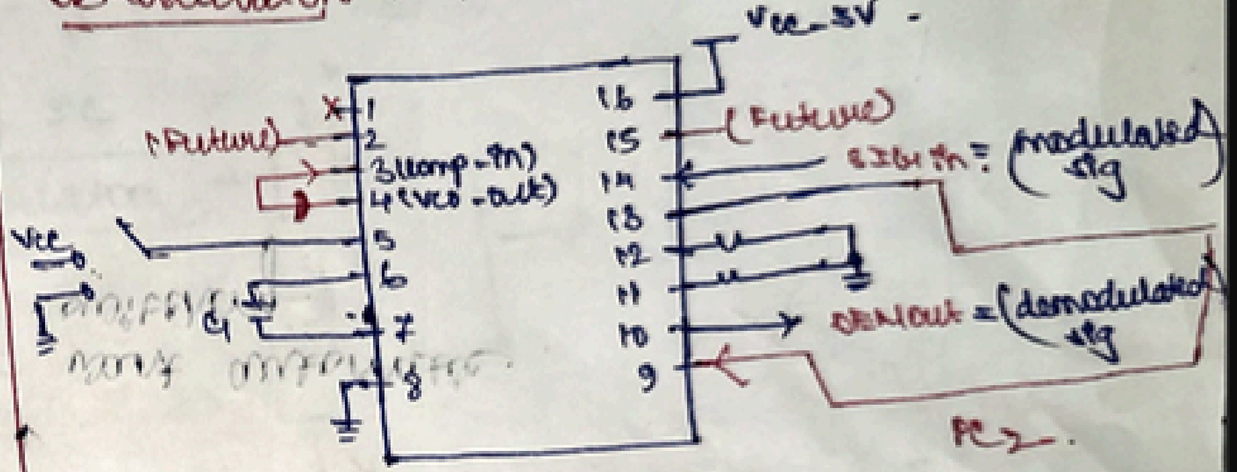
Matching Network &



$R_L = R_{in}$

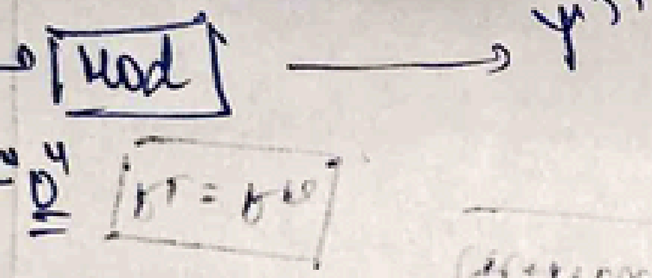
(Hi-matched)

DeModulator &

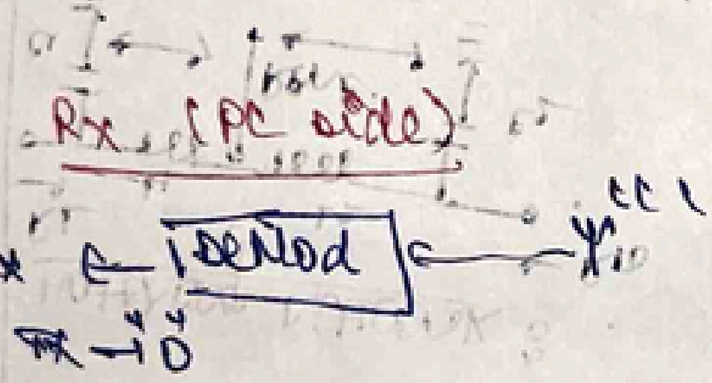


Future : Scheme 1 ⟷ Scheme 2
shifting for efficient
BW and power

Tx (PC side)



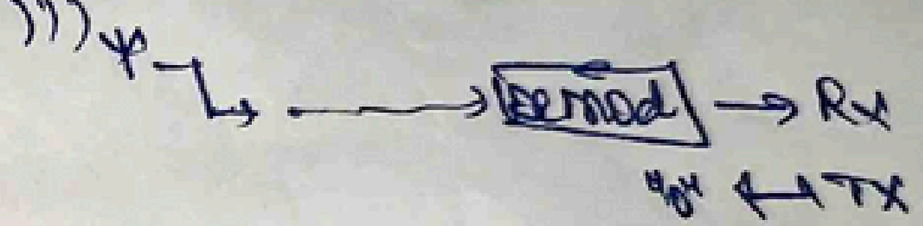
Rx (PC side)



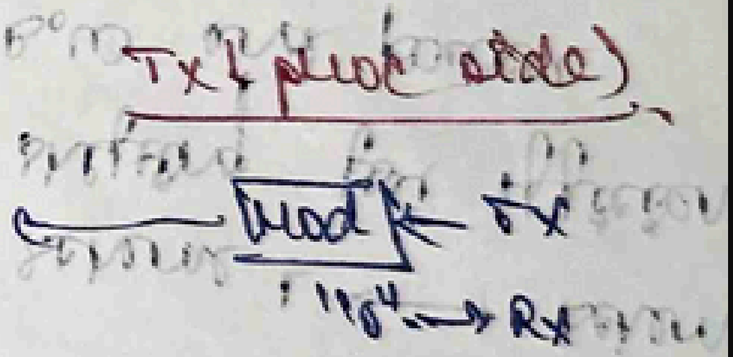
(All action at some fixed time)

switching mode

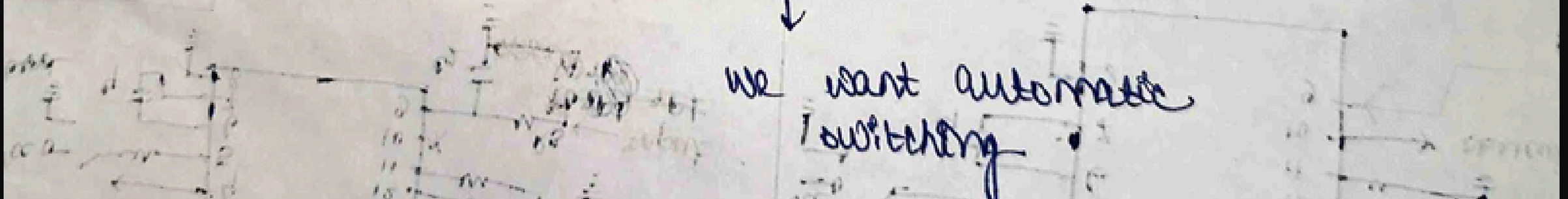
Rx (pico side)



Tx (pico side)

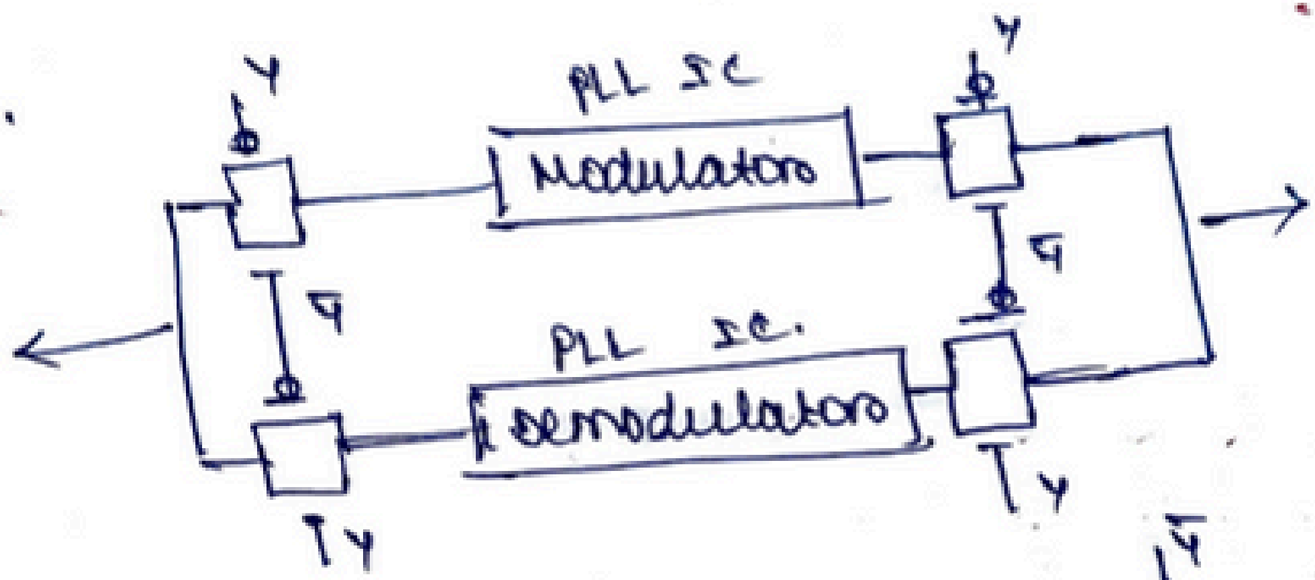


We want automatic switching

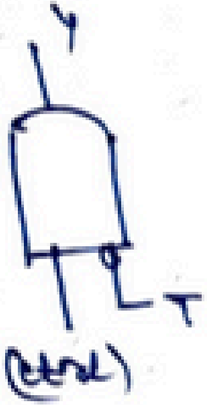


switching network

ctrol = 1
↳ go for demod on ADD side.



→ FOR PC side



→ FOR PD side

(→ FOR PC side → same circuit → just Y ⟷ Ȳ)

DELIVERABLES

What are the expected outcomes
of the project?

1. Successful wireless transmission of data from either side through a single pair of Antenna (programming/serial monitoring/sensor reading)
2. Intelligent interface to adapt to different types of client protocols and configure the Rx accordingly
3. Link layer to check if data was transmitted correctly or not, along with error detection
4. Application layer to give commands to initiate the communication
5. Adjustable data rate and bandwidth depending on range required and to save power
6. GUI for serial monitoring/plotting, sensor reading, setting data rate, duration of a plotting/monitoring cycle
7. Security protocol to ensure only specific Tx and Rx module pairs can communicate

EDL Project Gantt Chart

Universal Wireless Programmer

Project Start: 1/6/2025

TASK DESCRIPTION	PLAN START	PLAN END	ASSIGNED TO	Color
Project Proposal	1/6/2025	1/15/2025		
Project Advisor + Proposal	1/6/2025	1/15/2025	ALL	X
Milestone 1	1/15/2025	2/2/2025		
PPT	1/15/2025	2/2/2025	Dhruv	G
Video Presentation	1/15/2025	2/2/2025	ALL	R
BOM	1/15/2025	2/2/2025	Hardik, Anay	B
Circuit Diagrams	1/15/2025	2/2/2025	Kaustav, Saptarshi	P
Milestone 2	2/2/2025	2/15/2025		
Communication Testing	2/2/2025	2/8/2025	ALL	O
TX + Interface Testing	2/8/2025	2/12/2025	Hardik, Saptarshi	Y
Schematics	2/12/2025	2/15/2025	ALL	X
Milestone 3	2/20/2025	3/22/2025		
Integration of RX Interface	2/20/2025	3/5/2025	Dhruv, Kaustav	R
Expansion of RX to multi-device	3/5/2025	3/15/2025	Anay, Hardik	P
Protocol + Additional features	3/15/2025	3/20/2025	ALL	G
Report	3/20/2025	3/22/2025	ALL	O
Milestone 4	3/22/2025	4/12/2025		
Final Testing	3/22/2025	4/1/2025	ALL	R
Report + PPT	4/1/2025	4/12/2025	ALL	P

Weekly goals and work distributions are subject to changes.

THANK YOU